Mo-99 Production Utilizing "Target-only" Reactor Design

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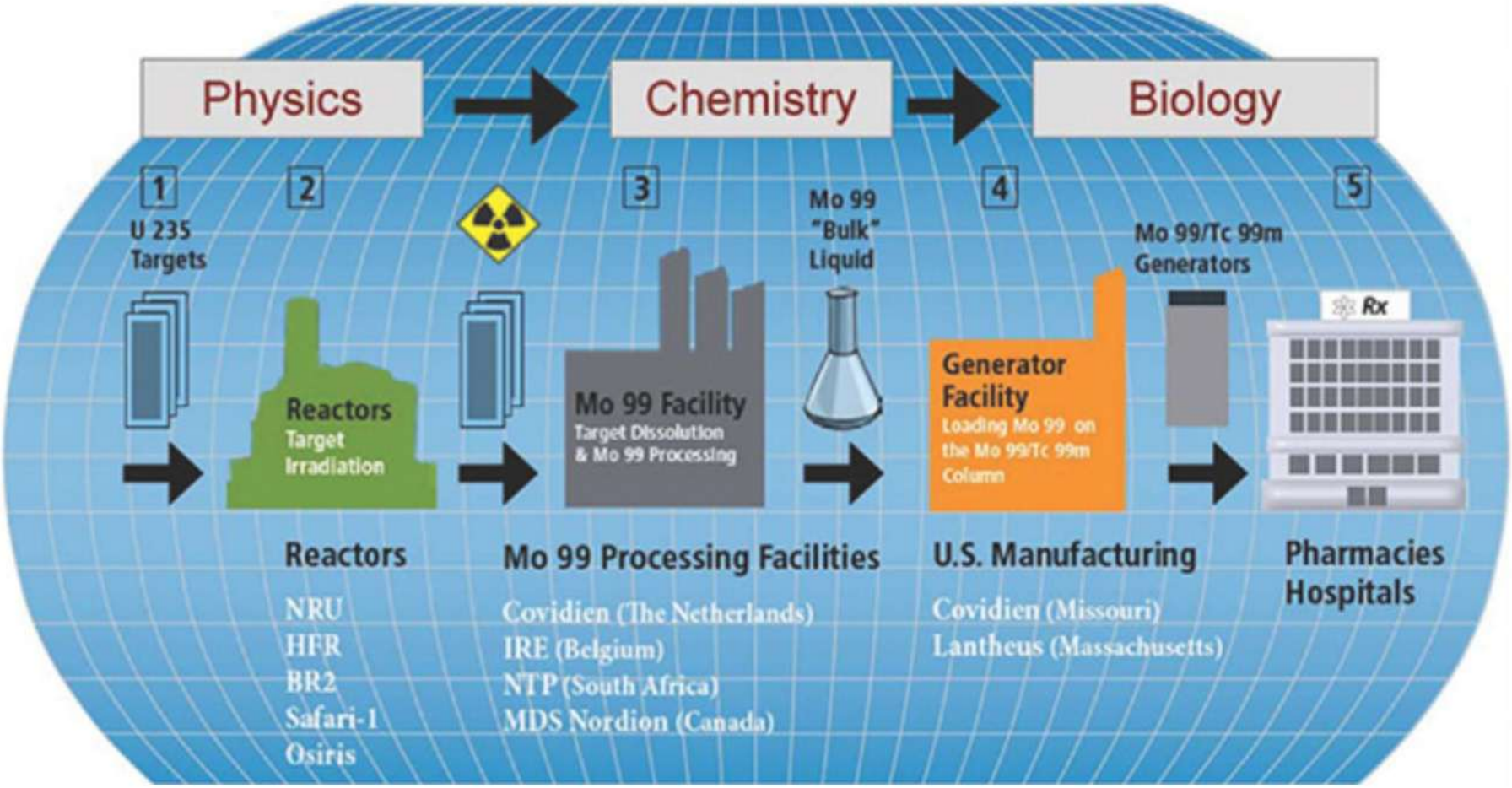
Mo-99 is currently produced in 6 reactors scattered throughout the world



Mo-99 production process
Source: TRIUMF, inspired by graphics from Nordion

Those reactors are located around the world, but none in the US

Source: www.nature.com

NRU: 135 MW_{th} ; first critical November 3, 1957
HFR: 45 MW_{th} ; first critical November 9, 1961
BR2: 50-80 MW_{th} ; first critical January1963
Safari-1: 20 MW_{th}; first critical March 18, 1965
Osiris: 70 MW_{th}; first critical 1966
OPAL: 20 MW_{th}; first critical August 12, 2006

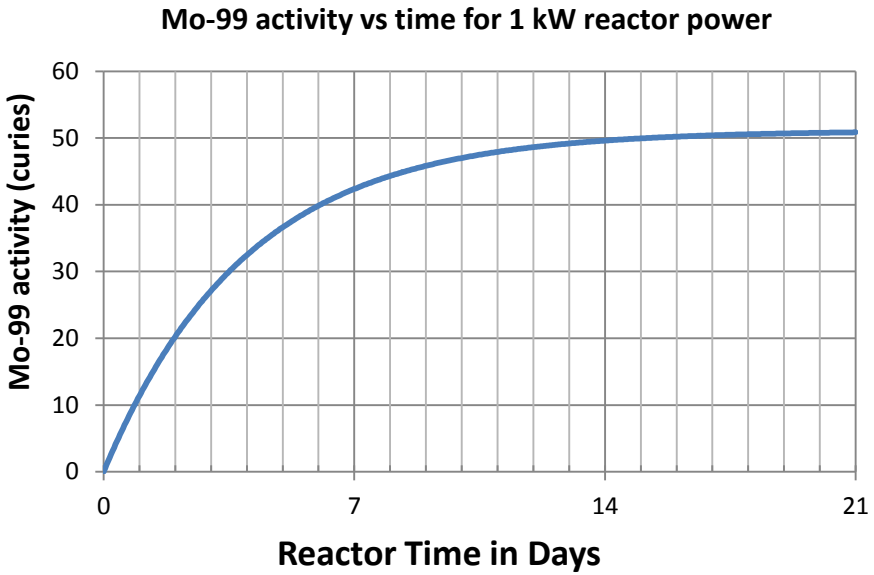
Commonality between reactors include:

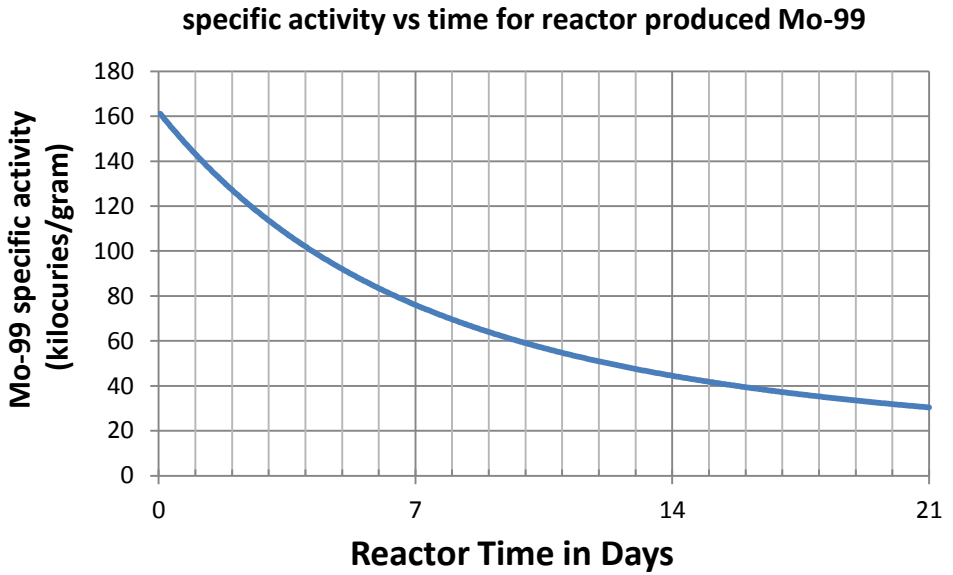
- All but one are very old
- All but one use HEU for Mo-99 production
- All operated at fission rates that are >100 greater than what is needed for Mo-99 production
- All are heavily subsidized by their respective government

What can be done?

- Do out of the box thinking for Mo-99 production
  - Neutron activation in power reactor
  - Neutron activation with accelerator produced neutrons
  - γN production using Mo-100
- Design a production reactor that is sized to meet the industry's needs
  - Solution reactors
    - Self critical
    - Accelerator driven

Mo-99 production by fission



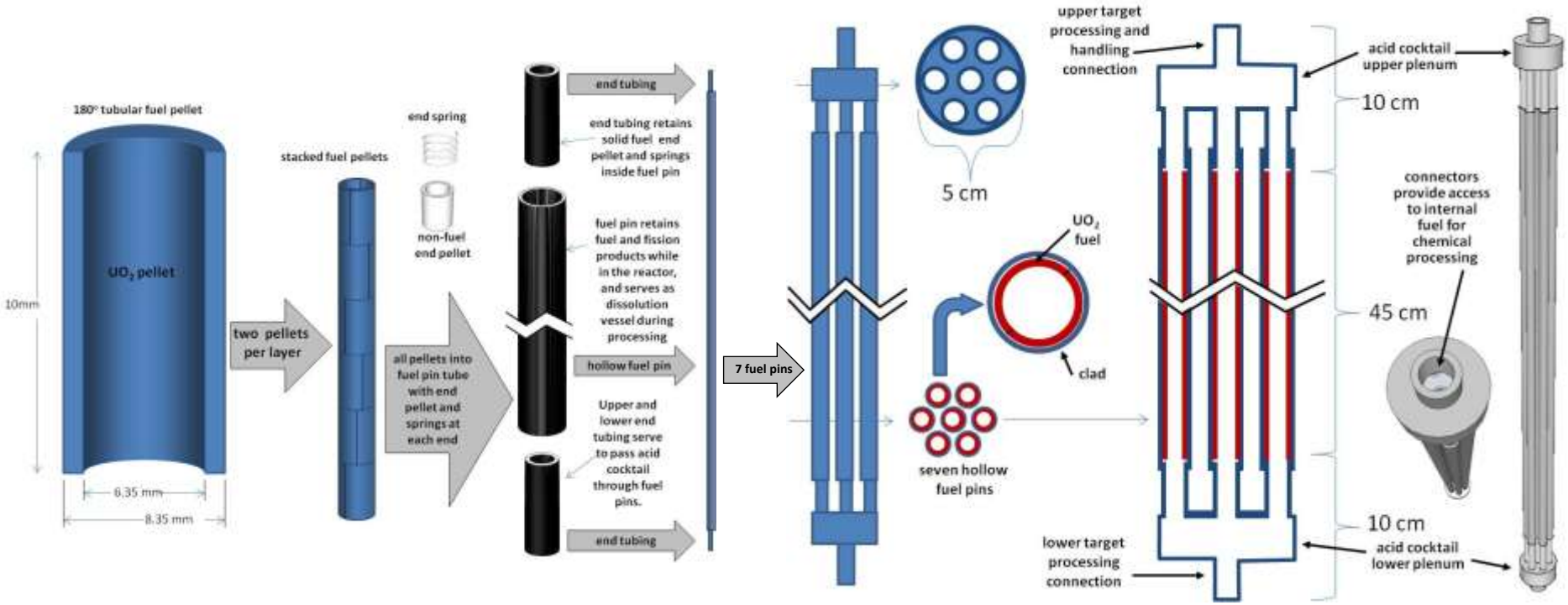


- **A 50 kW target produces 2150 curies of Mo-99 after one week in operation**
- **With production losses and measurement in six-day-curies, this target would produce 350 six-day-curies.**
- **Processing 19 targets per week would provide 6,650 six-day-curies for the market**
- **The US market demand in 2012 was 6,000 six-day-curies**

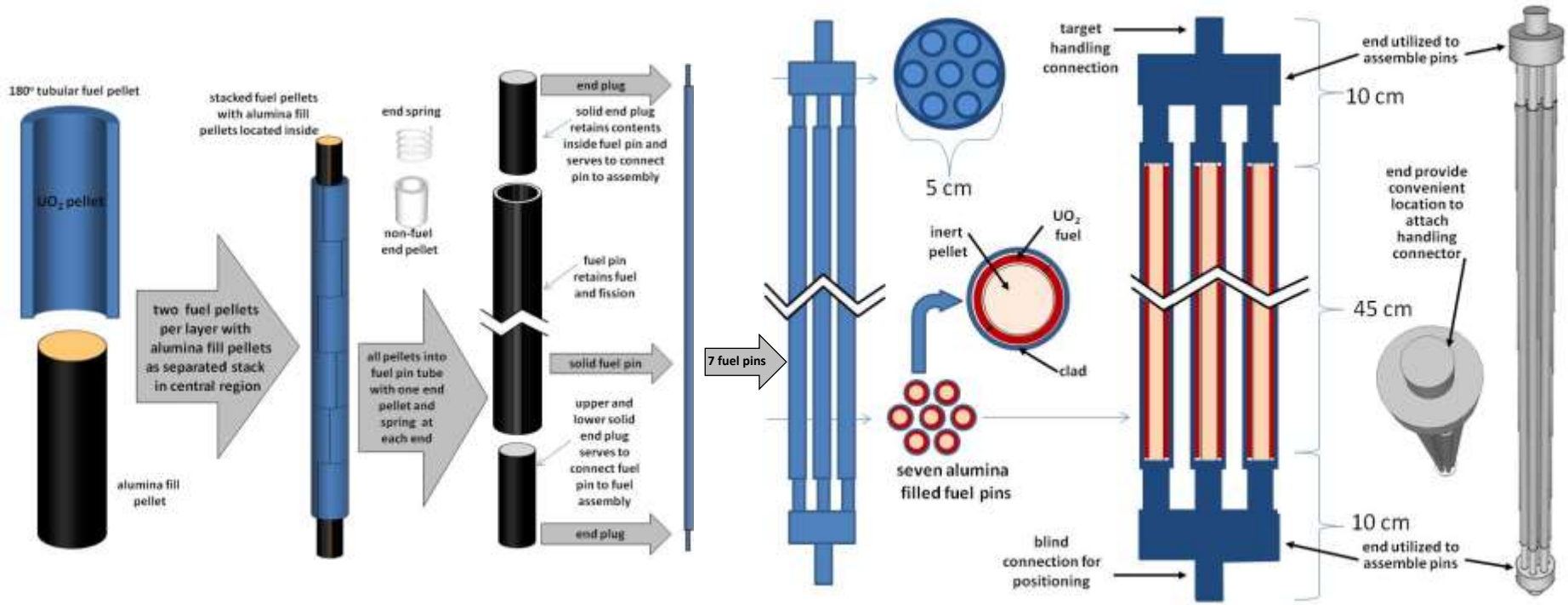
Eden's Approach

- Design a fuel element that facilitates the recovery of the Mo-99 in a timely manner
- Design a standard water moderated and cooled reactor that meets the needs with the minimum inventory of fuel
- Design a facility that co-locates the reactor and hot cells to minimize decay losses

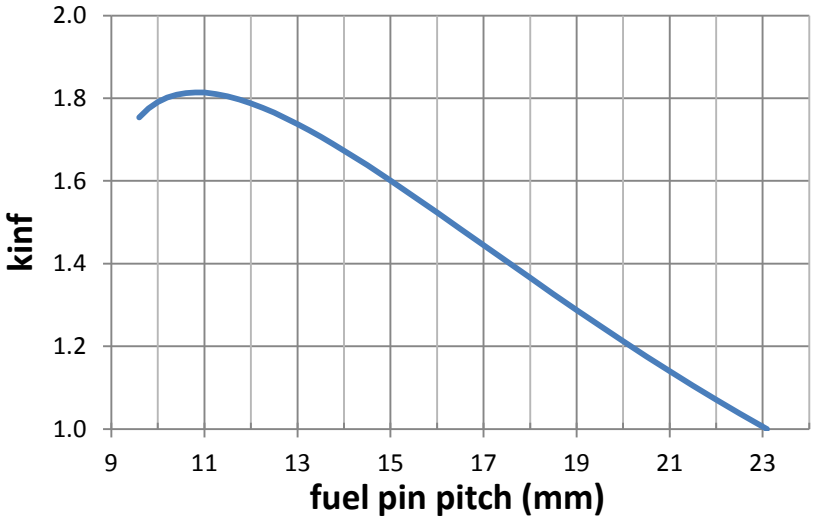
Target Fuel Assembly

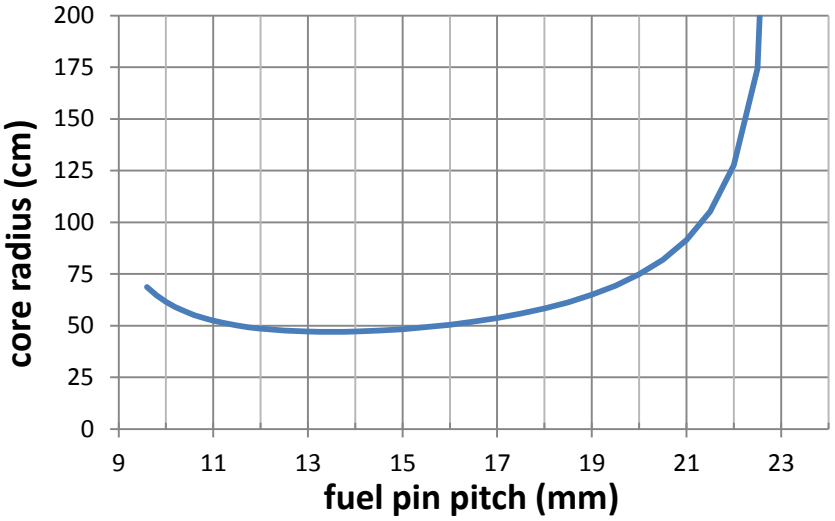


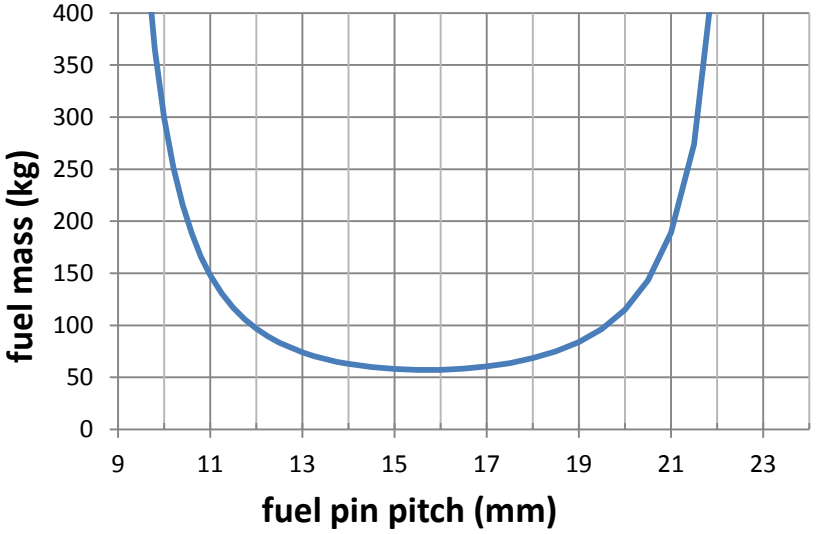
Driver Fuel Assembly

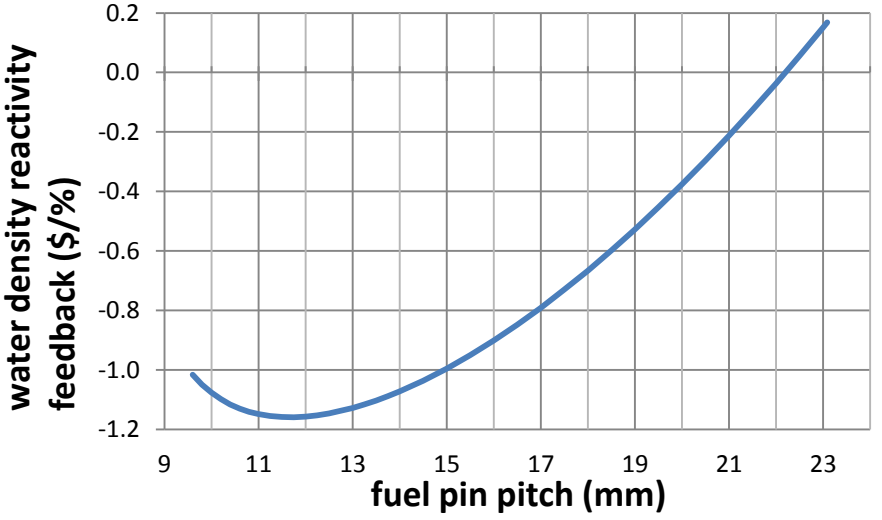


Bare reactor calculations as a function of fuel pin pitch with hollow 19% enriched fuel

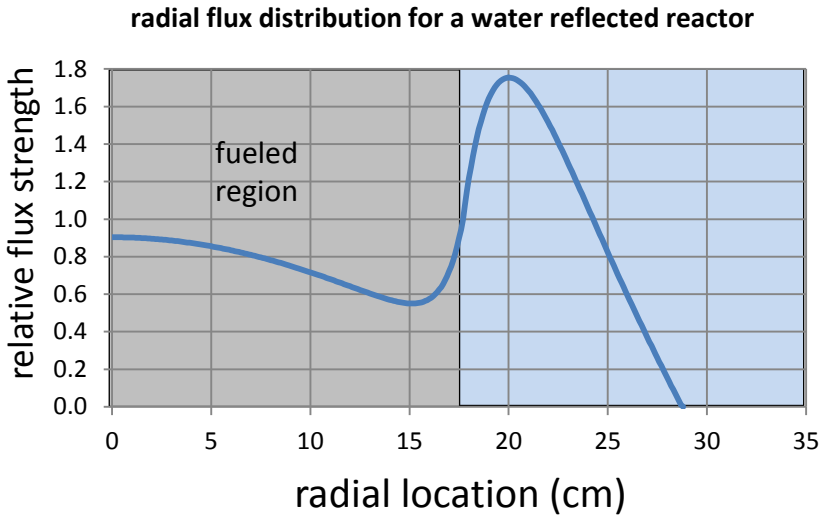


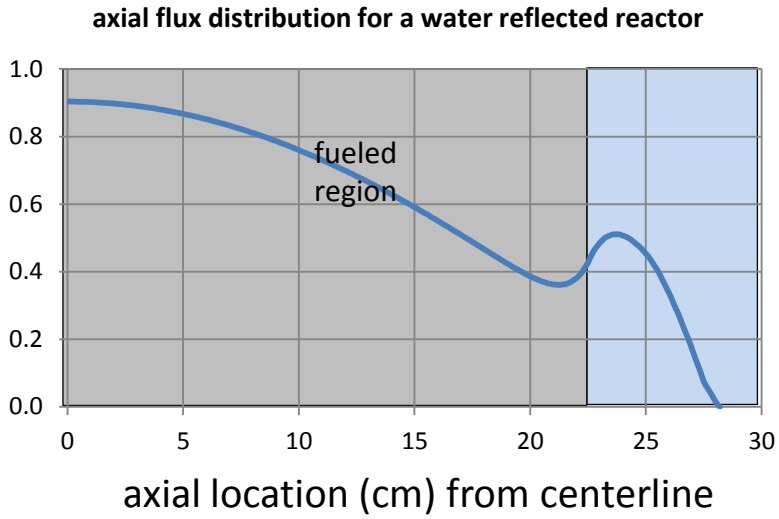






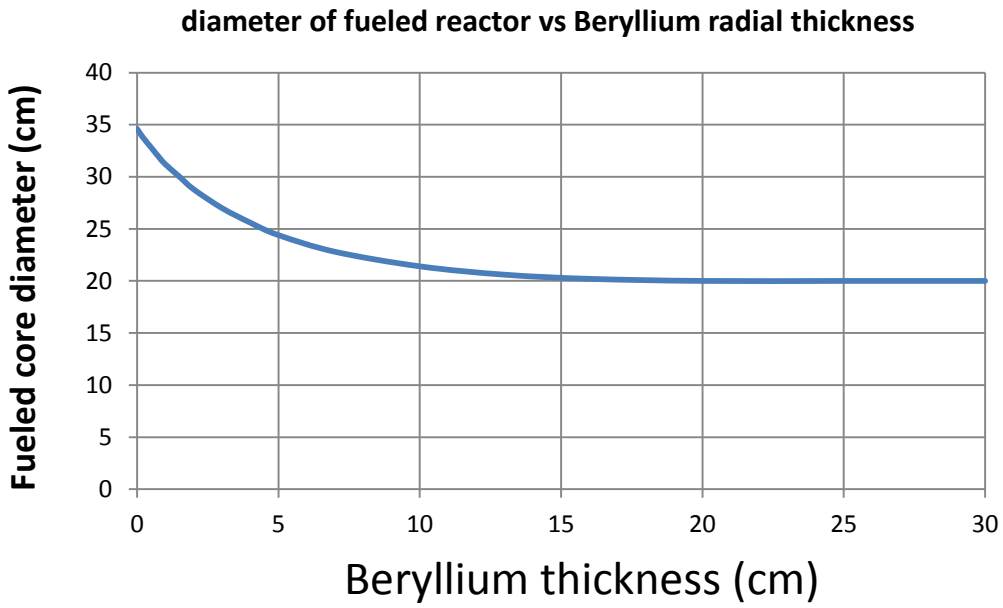
Flux and power distribution for water reflected reactor using described fuel



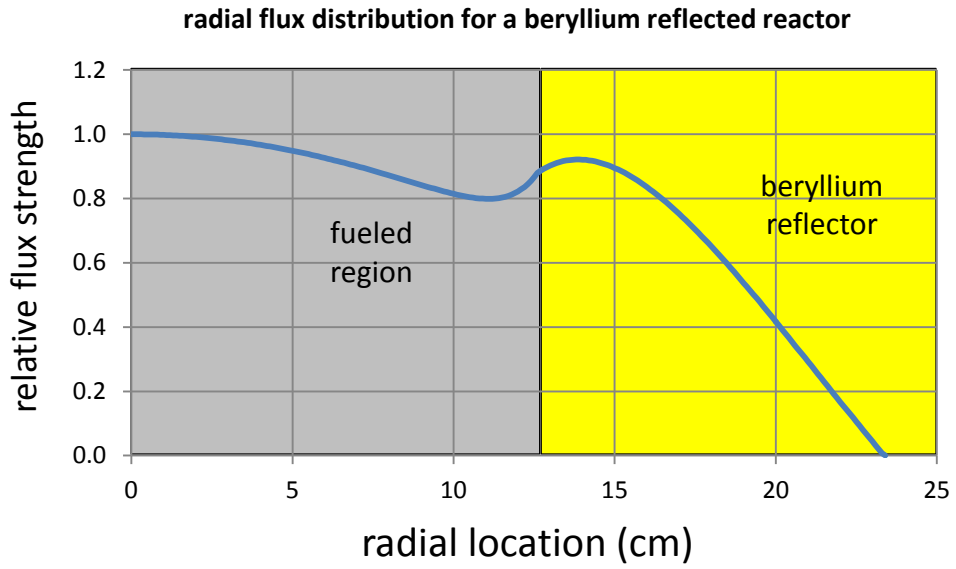


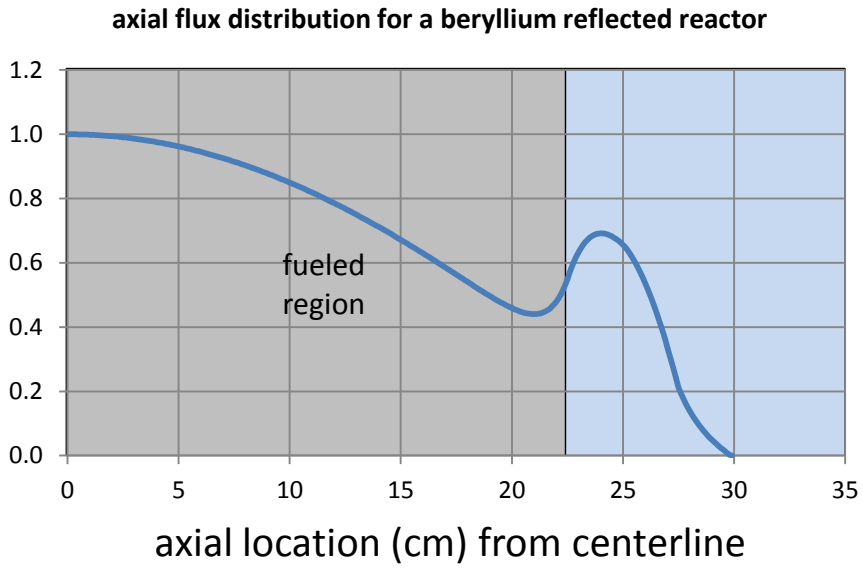
- **Both the size and peak-to-average power distribution are improved through the proper use of reflector**
- **The radial diameter of the fuel core is reduced from 50 cm to 35 cm through the use of a water reflector**
- **The peak-to-average power distribution is reduced from 3.64 to 1.92 utilizing a water reflector**

The size of the reactor can be further reduced using a beryllium reflector



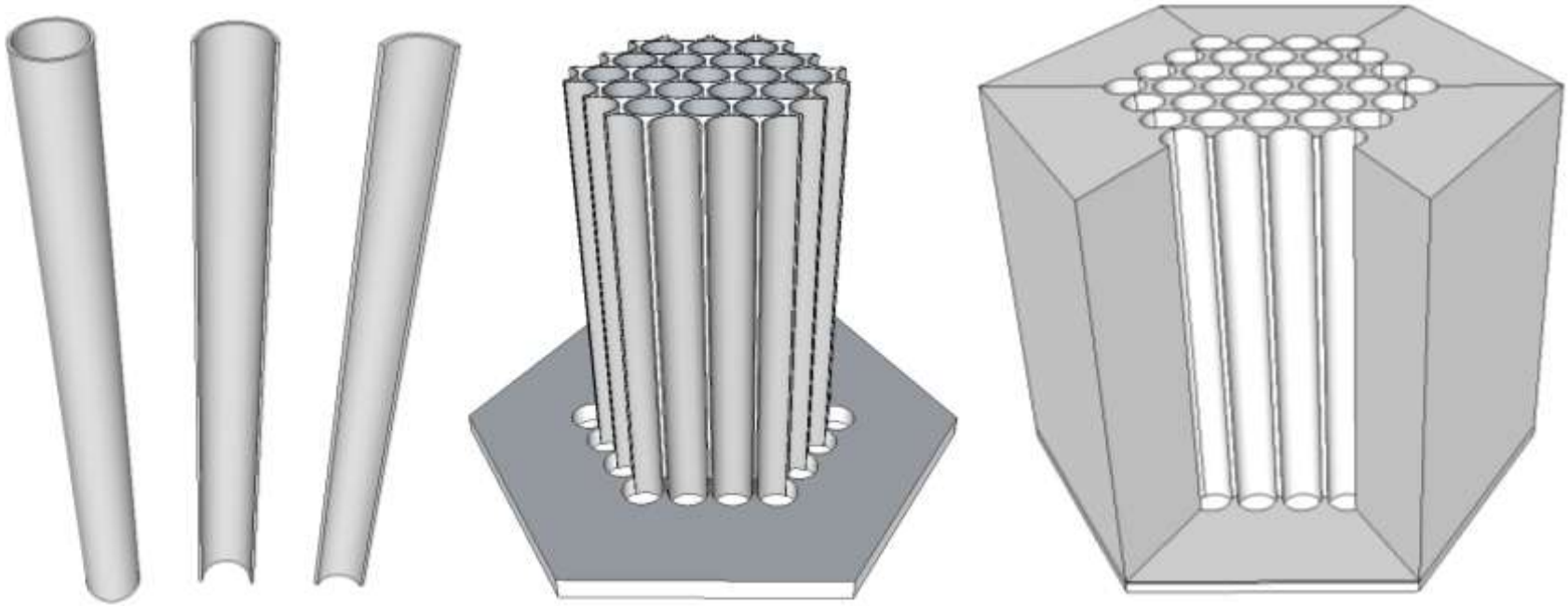
Flux and power distribution for beryllium reflected reactor using described fuel



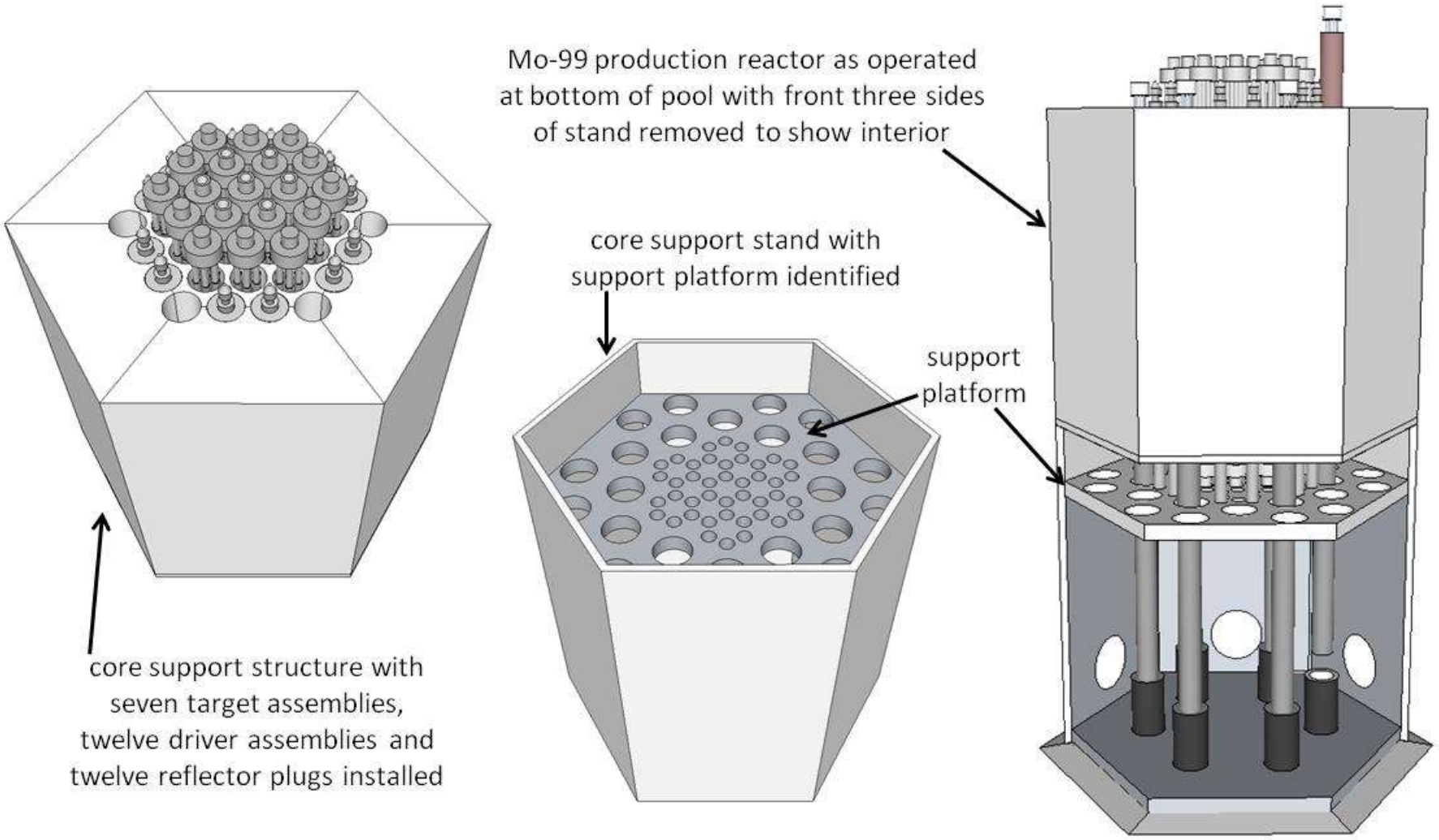


- **The radial diameter of the fuel core could be reduced from 35 cm to 20 cm through the use of a beryllium radial reflector**
- **For our design we reduced the diameter to 25 cm retaining excess reactivity for reactor control**
- **The peak-to-average power distribution is reduced from 1.92 to 1.50 utilizing a beryllium radial reflector**

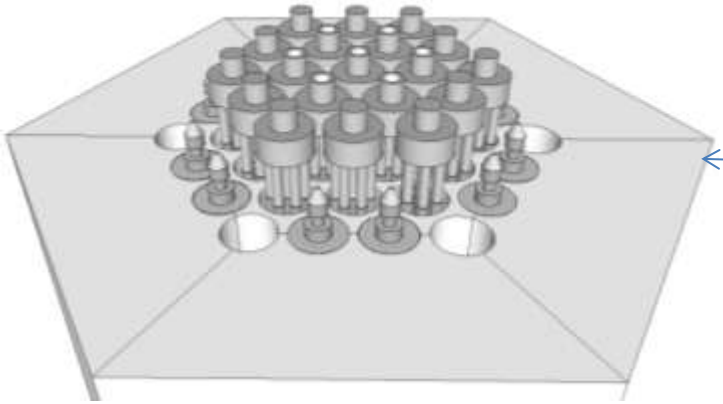
Core Support Structure



Core and Core Support Stand

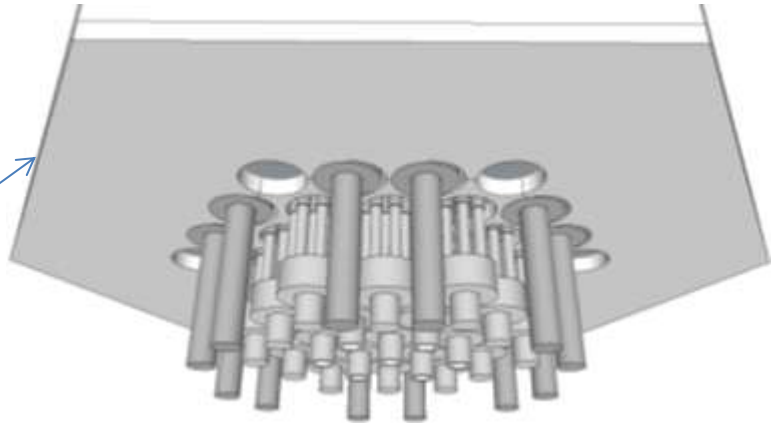


Core as viewed from top and bottom

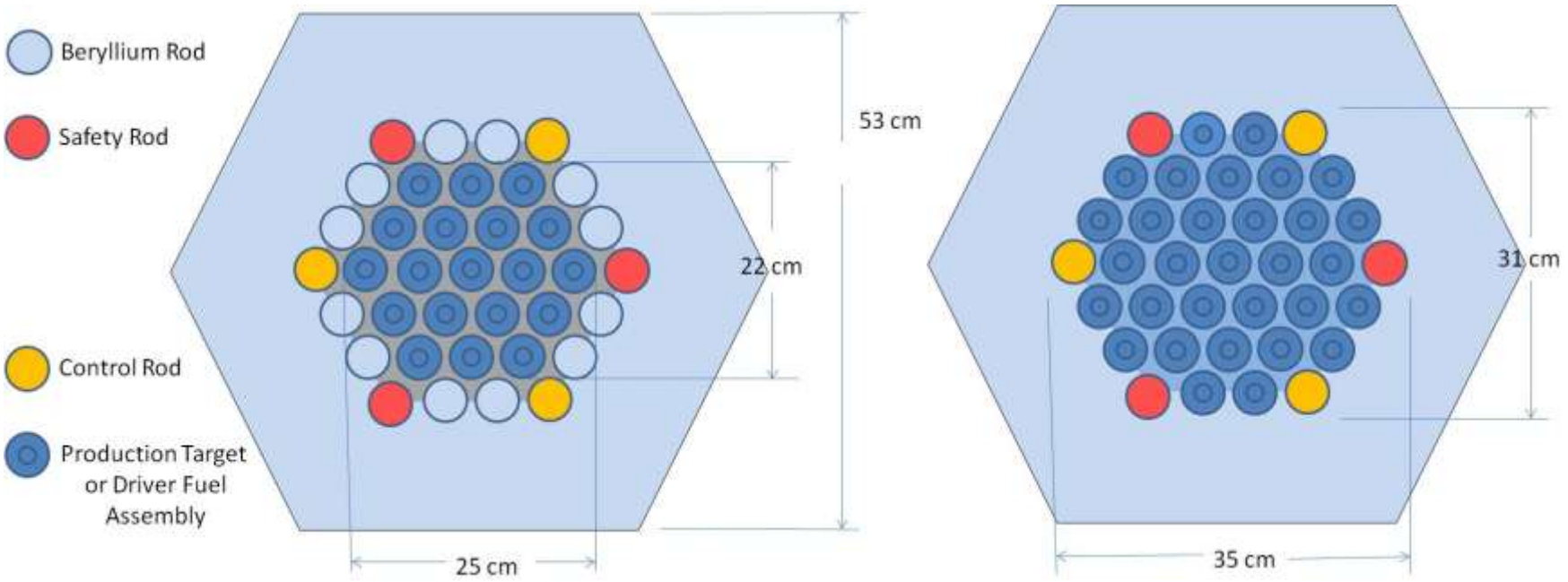


core arrangement from top

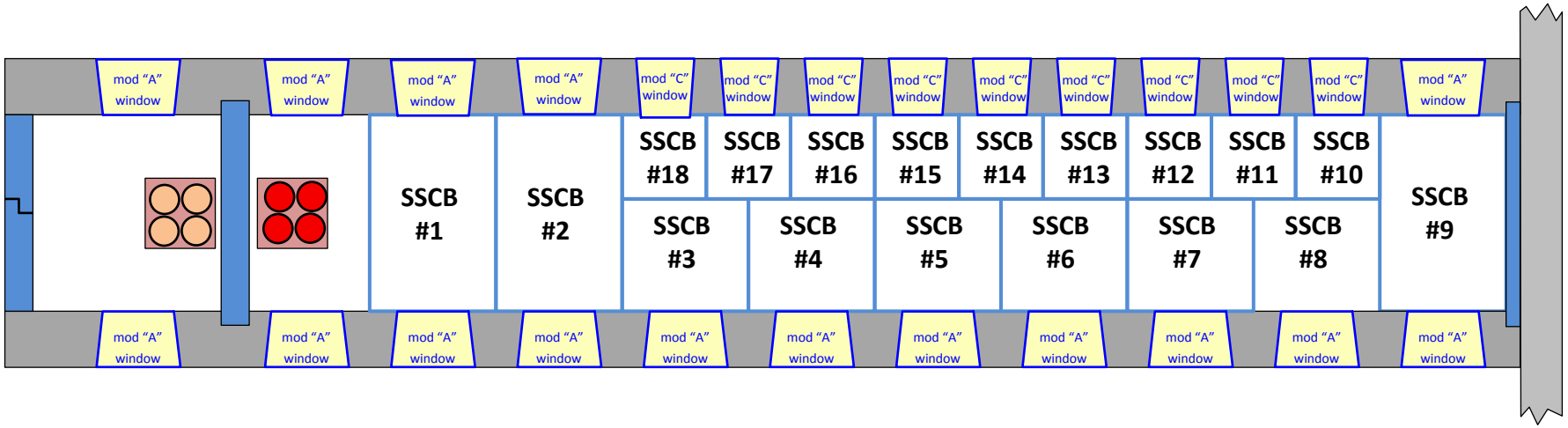
core arrangement from bottom



Mo-99 Production Reactor Configuration Options



Mo-99 Production facility hot cell arrangement

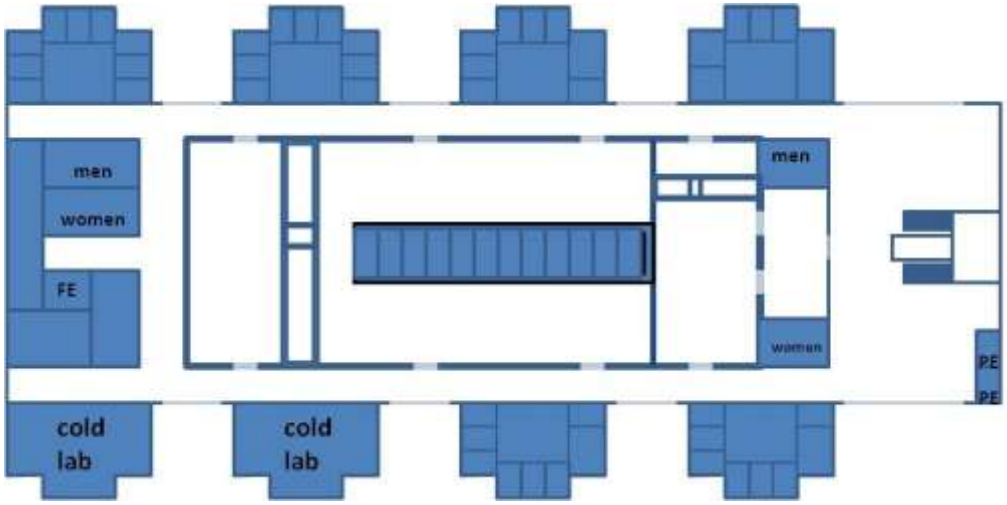


Stainless Steel Containment Box (SSCB) designated use

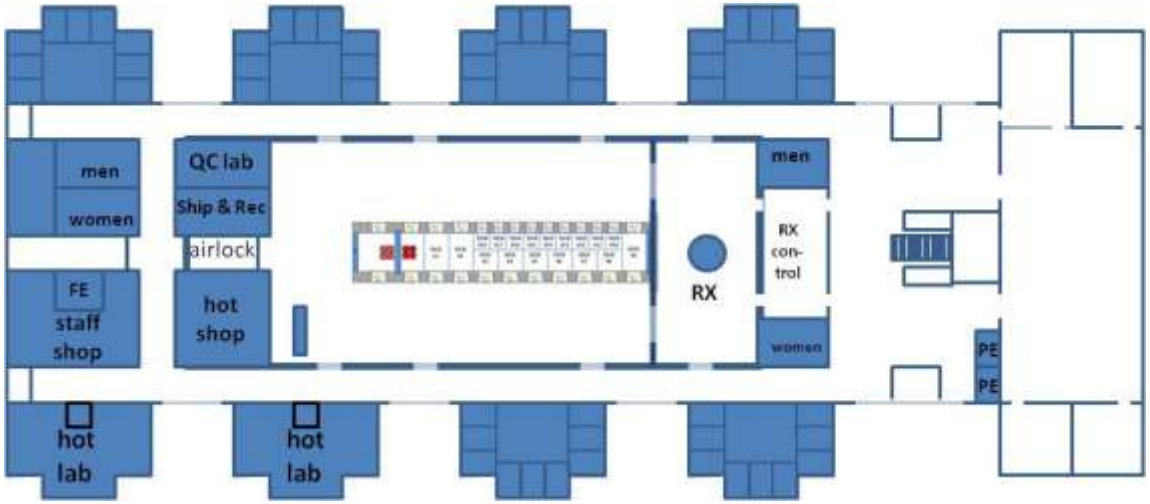
- #1: waste packaging box
- #2: asset recovery box
- #3 thru #8: target extraction boxes
- #9: target receiving box
- #10, #12, #13, #15, #16, #18: Mo-99 purification boxes
- #11, #14, #17: Mo-99 packaging Boxes

The Mo-99 facility will house the reactor, hot cell and work location for employees on the ground and 2nd floor

2nd floor



1st floor



While the basement will house the mechanical equipment for reactor and hot cell along with the waste decay storage area